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OPTICAL FIBER TRANSMISSION LINE

FIELD OF THE INVENTION

This invention relates to an optical fiber transmission line which chromatic dispersion is controlled.

BACKGROUND OF THE INVENTION

In a long haul optical fiber transmission system, dispersion compensating fibers are disposed at appropriate intervals because it is necessary to control accumulated chromatic dispersion within a predetermined value (See U.S. Pat. No. 5,361,319)

In wavelength division multiplexing (WDM) optical transmission that has attracted public attention as a means to increase a transmission capacity, there is another problem that accumulated chromatic dispersion differs per wavelength since chromatic dispersion of a transmission optical fiber differs per wavelength (this is called as a dispersion slope). At the beginning, although a configuration to compensate the difference of accumulated chromatic dispersion values between the wavelengths at a receiver or transmitter side is proposed, the dispersion amount that the transmitter or receiver side can compensate is limited. In addition, the permissible difference of dispersion values tends to decrease as a bit rate per channel increases.

Therefore, such an optical transmission line has been proposed that locally compensates the accumulated chromatic dispersion per optical repeating span and widely compensates the accumulated chromatic dispersion per predetermined number of optical repeating spans simultaneously (See, for example, Japanese Laid-Open Patent Publication No. 2000-82995, T. Naito et al., ECOC '99 PDPD2-1, Nice, 1999, and EP 1035671 A2).

In the configurations disclosed in the Japanese Laid-Open Patent Publication No. 2000-82995 and paper by Naito et al, when an optical fiber having the dispersion value between −20 ps/nm/km and −45 ps/nm/km is used as a negative dispersion fiber, the ratio of the length of the negative dispersion fiber to a positive dispersion fiber increases. Consequently, optical input power given to the negative dispersion fiber having a relatively small effective core area increases and accordingly signal degradation due to the nonlinear effect also increases.

In the configuration disclosed in EP 1035671 A2, since the local dispersion Dlocal is set to a positive value (between +1 ps/nm/km and +4 ps/nm/km), a dispersion compensating fiber to be disposed at a wide area compensating span must be a negative dispersion fiber. In consideration of practical maintenance of a system, it is preferable that the interval of repeaters should be 20 km or more and also the length of each repeating span should

be approximately equivalent. However, if a negative dispersion fiber with a dispersion value of −50 ps/nm/km or less (absolute value is 50 ps/nm/km or more) is used for the compensation of the wide area, the length of approximately 10 km is sufficient and this is very different to the lengths of other repeating spans. To equalize the lengths of all repeating spans, it is necessary to provide a third optical fiber with a different chromatic dispersion value as a dispersion fiber for the wide area compensation, which means to use three kinds of optical fibers. This makes the maintenance of the system very difficult. For instance, when broken parts are to be connected, it is required to provide three kinds of optical fibers and insert one of the fibers after selecting suitable one for the optical fiber with the broken parts.

In addition, since the effective core area of a negative dispersion fiber is small, it is necessary to decrease the optical input power to reduce the degradation of transmission performance due to nonlinear effect in the negative dispersion fiber at the repeating span for wide area compensation. For example, it is necessary to dispose an attenuator immediately in front of the negative dispersion fiber.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide

a low nonlinear optical fiber transmission line in which two kinds of optical fibers flatten chromatic dispersion.

An optical fiber transmission line according to the invention consists of a plurality of local dispersion compensating spans, a wide area dispersion compensating spans disposed at predetermined intervals, and optical repeating amplifiers to connect each span, wherein the local dispersion compensating span consists of a first optical fiber of positive dispersion having an effective core area of 130 μm^2 or more and a second optical fiber having a negative dispersion value of − 50 ps/nm/km or less to transmit an optical signal output from the first optical fiber, and the wide area dispersion compensating span consists of a third optical fiber having the same configuration and composition with the first optical fiber.

Owing to the above dispersion control, satisfactory transmission characteristics can be realized even on the long haul transmission. Furthermore, the maintenance control becomes easier because practically only two kinds of the optical fibers are used.

Preferably, the distance of the wide area dispersion compensating span is substantially equal to that of the local dispersion compensating span. Accordingly, optical amplifiers of the same configuration can be used for both spans. This also makes the maintenance control easier.

Preferably, the average chromatic dispersion after the dispersion compensation by the second optical fiber at the local dispersion compensating span should be between −4 ps/nm/km and −1 ps/nm/km. This can realize high speed and large capacity WDM transmission on the long haul transmission of 1000 km or more.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings, in which:

FIG. 1 shows a schematic block diagram of a first embodiment according to the invention;

FIG. 2 shows a schematic diagram of distance variation of accumulated chromatic dispersion of the embodiment shown in FIG. 1;

FIG. 3 shows measured examples indicating the influence of dispersion value of a negative dispersion optical fiber 20;

FIG. 4 shows measured examples of the optimum range of Dlocal; and

FIG. 5 shows the measured preferable range of the effective core areas of positive dispersion optical fibers 18 and 22.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the invention are explained below in detail with reference to the drawings.

FIG. 1 shows a schematic block diagram of a first embodiment according to the invention, and FIG. 2 shows a schematic diagram of a dispersion map, namely distance variation of accumulated chromatic dispersion.

Reference numeral 10 denotes an optical transmitter to launch a WDM optical signal onto an optical transmission line 12, and reference numeral 14 denotes an optical receiver to receive the WDM optical signal propagated on the optical transmission line 12. The optical transmission line 12 consists of a plurality of repeating spans partitioned by optical amplifiers 16 (16-1, 16-2…). In this embodiment, the accumulated chromatic dispersion and dispersion slope are locally compensated per repeating span and the accumulated chromatic dispersion is widely compensated per predetermined number of the repeating spans simultaneously. The repeating span to locally compensate the chromatic dispersion is called as a local compensating span and the repeating span to widely compensate the chromatic dispersion is called a wide compensating span. In the embodiment shown in FIG. 1, the local compensating span equals to one repeating span. One repeating span after six local compensating spans becomes the wide compensating span. In

the embodiment shown in FIG. 1, the six local compensating spans and the following one wide compensating span form a basic unit, and this basic unit is repeated until reaching the optical receiver 14.

The local compensating span consists of a positive dispersion optical fiber 18 (18-1, 18-2…) and a negative dispersion optical fiber 20 (20-1, 20-2…) to transmit the output light from the positive dispersion optical fiber 18. The wide compensating span consists of a positive dispersion optical fiber 22 alone that composes the same optical fiber with the positive dispersion optical fiber 18. In this embodiment, one repeating span is set to 20 km or more, the effective core area Aeff of the positive dispersion optical fibers 18 and 22 is set to 130 μm^2 or more, and the negative dispersion optical fiber 20 consists of an optical fiber with the chromatic dispersion of −50 ps/nm/km or less, namely an optical fiber with the negative chromatic dispersion having the absolute value of 50 ps/nm/km or more.

As shown in FIG. 2, the chromatic dispersion and length of the positive dispersion optical fibers 18, 22 and negative dispersion optical fiber 20 are set so that the chromatic dispersion value after the local dispersion compensation, namely the local average chromatic dispersion Dlocal becomes a negative value and the chromatic dispersion value after the wide dispersion

compensation, namely the wide chromatic dispersion value Davg becomes a positive value or negative value near to zero. In principle, the length of each repeating span is identical. With the above configuration, optical amplifiers with the same configuration and gain characteristics can be used for every optical amplifier 16 and therefore the maintenance becomes much easier.

Preferably, Dlocal should be approximately between –1 ps/nm/km and –4 ps/nm/km. Owing to this dispersion control, the transmission capacity increases 1.5 times as much as that of the conventional systems.

In this embodiment, the dispersion slope is not compensated at the wide compensation stage. Accordingly, the accumulated chromatic dispersion per wavelength expands in the period of the wide compensating span. However, one of the merits of this embodiment is that the maintenance becomes much easier since the optical transmission line part can be formed using only two kinds of optical fibers. Moreover, even on 10000 km transmission, the transmission characteristics hardly receive any bad influence from not compensating the dispersion slope in the wide compensating span.

The desirable dispersion values of the negative dispersion optical fiber 20 are measured at 7750 km and 10000 km transmissions respectively. The measured results are shown in FIG. 3. The horizontal axis expresses the dispersion values of the negative

dispersion optical fiber 20 and the vertical axis expresses the average values of Q^2 (dB). Obviously from FIG. 3, the chromatic dispersion value of the negative dispersion optical fiber 20 should set to –50 ps/nm/km or less.

The optimum range of the local dispersion value Dlocal is measured. The measured results are shown in FIG. 4. Here, the transmission distance is 6000 km and 16 wavelengths of 10 Gbit/s are multiplexed. The wide compensation is performed every seven repeating spans. Dlocal is scanned through varying the dispersion values of the negative dispersion optical fiber 20. The other parameter values are as mentioned above. The horizontal axis expresses Dlocal (ps/nm/km) and the horizontal axis expresses Q^2 (dB). Obviously from FIG. 4, satisfactory results can be obtained by setting Dlocal to the range between –1 ps/nm/km and –4 ps/nm/km.

The influence of the effective core area Aeff of the positive dispersion optical fibers 18 and 22 is researched. FIG. 5 shows the measured result. The horizontal axis expresses the effective core area of the positive dispersion optical fibers 18, 22 and the vertical axis expresses Q^2 (dB). The transmission distance is 6000 km and 16 wavelengths of 10 Gbit/s are multiplexed. Dlocal is set to –4 ps/nm/km and the wide compensation is performed every seven repeating spans. Obviously from FIG. 5, the effective core area Aeff of the positive dispersion optical fibers 18 and 22 should

preferably set to 130 μm^2 or more.

The material dispersion of the positive dispersion fiber is approximately +20 ps/nm/km at the 1.5 μm band, which is substantially the maximum value. On the other hand, the negative dispersion fiber has the negative dispersion and negative dispersion slope at the 1.5 μm band, and its effective core area is approximately between 20 and 30 μm^2, which is substantially the maximum value.

As readily understandable from the aforementioned explanation, according to the invention, satisfactory long haul transmission characteristics can be realized by using two kinds of optical fibers. In addition, the dispersion management and maintenance become much easier, and satisfactory transmission characteristics can be realized at high speed and large capacity WDM transmission.

While the invention has been described with reference to the specific embodiment, it will be apparent to those skilled in the art that various changes and modifications can be made to the specific embodiment without departing from the spirit and scope of the invention as defined in the claims.